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THE CURRENT STATUS OF RESEARCH AND THEORY IN HUMAN PROBLEM SOLVING.

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PROBLEM-SOLVING THEORIES IN THREE AREAS - TRADITIONAL (STIMULUS-RESPONSE) LEARNING, COGNITIVE-GESTALT APPROACHES, AND COMPUTER AND MATHEMATICAL MODELS - WERE SUMMARIZED. RECENT EMPIRICAL STUDIES (1960-65) ON PROBLEM SOLVING WERE CATEGORIZED ACCORDING TO TYPE OF BEHAVIOR ELICITED BY PARTICULAR PROBLEM-SOLVING TASKS. ANAGRAM, "INSIGHT," "WATER-JAR," AND ARITHMETIC PROBLEMS WERE CONSIDERED SOLVABLE BY COVERT TRIAL-AND-ERROR BEHAVIOR. IT WAS SUGGESTED THAT "SWITCH-LIGHT," CLASSIFICATION, PROBABILITY-LEARNING, AND NUMEROUS "MISCELLANEOUS" TASKS SHOULD BE APPROACHED BY OVERT TRIAL-AND-ERROR METHODS. BY DISCUSSING PROBLEM SOLVING IN TERMS OF OVERT VERSUS COVERT TRIAL-AND-ERROR BEHAVIOR, THE REPORT PRESENTED A NEW APPROACH TO THE STUDY OF HUMAN PROBLEM SOLVING THROUGH THE USE OF CATEGORICAL IDENTIFICATION OF PROBLEM-SOLVING TASKS. (GC)

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THE CURRENT STATUS OF RESEARCH AND THEORY IN HUMAN PROBLEM SOLVING

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PREFACE

The primary goal of the R & D Center for Learning and Re-Education is to improve cognitive learning in children and adults, commensurate with good personality development. Knowledge is being extended about human learning and other variables associated with efficiency of school learning. This operation is being performed through synthesizing present knowledge and through conducting research to generate new knowledge. In turn, the knowledge is being focused upon the three main problem areas of the Center: developing exemplary instructional systems, refining the science of human behavior and learning on the one hand and the technology of instruction on the other, and inventing new models for school experimentation, development activities, etc.

In this paper, Professor Gary Davis reviews the psychological literature on problem solving for the period 1960-1965. In his synthesis, most of the theoretical formulations may be categorized as traditional (S-R) learning, cognitive-Gestalt, and computer and mathematical models. From the analysis of the types of experiments, he generated two categories of problem solving behavior, implicit trial-and-error vs. overt trial-and-error, and specified the problem structure leading to one or the other form of problem solving. Although he mentions it only briefly in this paper, Professor Davis is engaged in one line of experimentation that will specify some of the factors that contribute to the complexity or difficulty of problem solving of either the implicit or overt type. This type of research contributes to our understanding of human problem solving in general, and has produced several suggestions for the teaching of effective problem solving techniques.

Herbert J. Klausmeier
Co-Director for Research
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ABSTRACT

Problem solving theories in three areas are summarized, traditional learning and cognitive-Gestalt approaches plus more recent computer and mathematical models of problem solving. Recent empirical studies are categorized according to the type of behavior elicited by the particular problem-solving task. Anagram, "insight," water-jar and arithmetic problems are considered to be solved by covert trial-and-error behavior (Type C problem-solving tasks). Switch-light, classification, probability-learning, and numerous "miscellaneous" tasks are approached by overt trial-and-error behavior (Type O problem-solving tasks).

I
INTRODUCTION

Research in human problem solving has a well-earned reputation for being the most chaotic of all identifiable categories of human learning. The outstanding quality which leads to this conclusion is the diversity of experimental procedures called "problem-solving" tasks. The tasks found in problem-solving literature range from match-stick, bent-nail, and jigsaw puzzles through anagram problems, concept-identification problems, arithmetic problems, and even some mental testing devices such as analogy problems and number-series problems. It is almost definitional of laboratory problem-solving experiments that virtually any semi-complex learning task which does not clearly fall into familiar areas of learning can safely be called "problem solving."

The present paper is an attempt to at least partially clarify the area of human problem solving. Specifically, the current major theoretical trends are reviewed and compared. Secondly, a learning approach to problem solving is presented in which problem solving is discussed in terms of overt vs. covert trial-and-error behavior. Finally, a summary of recent problem-solving research is categorized according to whether the particular task elicits primarily overt vs. implicit trial-and-error behavior.[1]

[1]The review extends from January, 1960, to June, 1965. Earlier papers are sometimes cited or discussed to maintain continuity.

II

RECENT THEORETICAL TRENDS

There is a striking unanimity in recent theoretical orientations to human thinking and problem solving. With only a few exceptions, basic learning principles have been used to interpret such complex behavior as problem solving, concept learning, and originality and creativity (e.g., Campbell, 1960; Gagné, 1964; Glucksberg, 1962, 1964a, 1964b; Goss, 1961; Kendler, 1964; Kendler & Kendler, 1962; Maltzman, 1960, 1962; Mandler, 1962; Mednick, 1962; Shultz, 1960; Staats & Staats, 1963). While these authors differ concerning details of their respective models, the underlying notion in all cases is the same, specifically, that associationistic behavioral laws established in comparatively simple classical and instrumental conditioning situations apply to complex human learning.

In addition to the learning approach to problem solving, there have been some papers representing other viewpoints, namely the traditional cognitive-Gestalt approach and the more recent computer simulation and mathematical models of problem solving.

LEARNING APPROACHES TO PROBLEM SOLVING

Perhaps the best-known recent learning approach to problem solving is the mediation-based horizontal-vertical processes model of Kendler and Kendler (1962). Briefly, two characteristics of problem solving are involved: (1) Behavior is a continuous process consisting of chained S-R associations ("horizontal" processes), and (2) at any one time behavior consists of several ongoing behavioral chains ("vertical" processes). Problem solving is said to consist of the integration of separate habits which, in their model, refers to the association of the response-produced cues from one behavior chain to the overt response of another chain. Their research (e.g., Kendler & Kendler, 1961) on inferential behavior with children, in which separately learned habits were combined or chained to solve the problem, and Maier's (1930) reasoning experiments were cited as primary sources of empirical support.

Staats (Staats & Staats, 1963) also presents a (verbal) mediation model of problem solving. His interpretation requires three steps of three S-R mechanisms: First, a stimulus object must elicit (implicitly or explicitly) a verbal response (Skinner's tacting). Second, the verbal response must then elicit an appropriate verbal response sequence which, presumably, would include the uses or functions of the stimulus object necessary for problem solution. The third step is the elicitation of the appropriate motor behavior by the verbal sequence.

These two mediational models appear difficult to reconcile since the Kendlers' model is based upon a definition of problem solving as combining previously unrelated associations or experiences, which approximately corresponds to Wertheimer's (1945) concept of productive thinking. On the other hand, Staats' model appears to be oriented toward problem solving defined as locating a correct (but low dominance) response alternative, which may reflect Wertheimer's reproductive thinking. If, however, combining unrelated responses is rephrased as located a correct combination of responses, then the models are less dissimilar.[2] That is, in addition to the fact that the Kendlers' response-produced cues probably correspond to the Staats' (implicit) verbal responses, both models require S to locate a low-probability correct response (or combination of responses) which is characteristic of all problem solving.

Two papers emphasize the role of trial-and-error learning in complex mental behavior. Mandler's (1962) analogic structures are considered central analogues of overt response sequences which develop as a result of overt trial-and-error learning and which permit implicit or covert trial-and-error behavior. He

[2] An implication, of course, is that Wertheimer's two types of thinking are reconcileable by the same rephrasing.

suggested that the analogic representation of a prior behavior sequence can be taken as an hypothesis to be overtly tried in a given situation. Mandler interpreted learning-set data in terms of the development of analogic structures and concluded that "cognitive sequelae" have been demonstrated in monkeys and rats, a conclusion not allowable with strict verbal mediational models of problem solving.

Campbell's (1960) paper, with the startling title of Blind Variation and Selective Retention in Creative Thought as in Other Knowledge Processes, creates the first impression of being a rather extreme trial-and-error interpretation of cognitive processes. As it turns out, his views in some respects are quite similar to those of Mandler. His main points are as follows: (1) A blind-variation-and-selective-retention process is fundamental to all increases in knowledge. (2) The many processes which shortcut the complete blind-variation-and-selective-retention process were themselves achieved originally by blind variation and selective retention. (3) Such short-cut processes contain in their own operation a blind-variation-and-selective-retention process at some level, substituting for overt locomotor behavior. This same model of blind variation and selective retention underlies both problem solving and natural selection in evolution.

Contrasting with the strong trial-and-error emphasis of both Mandler and Campbell, Shultz (1960) analyzed problem solving from a more molar transfer-of-training viewpoint. Several traditional problem-solving tasks (detour, anagrams, and water-jar problems) were seen as instances of negative transfer or proactive inhibition stemming from the presence of incompatible response tendencies. Shultz noted that his transfer-of-training approach has the advantages of integrating problem solving with learning and of suggesting several quantifiable problem-solving variables, e.g., degree of Task A learning and similarity of Task A to Task B.

Maltzman (1960) and Mednick (1962) present associationistic interpretations of originality and creativity.[3] Creativity and problem solving are intimately related since uncommon responses are required by both. Also, many authors speak of "creative problem solving" (e.g., Hoffman, 1961; Jacobsen & Asher, 1963; Parnes & Meadow, 1960). Mednick's basic hypothesis takes the form of a definition: "The creative thinking process is the forming of associative elements into new combinations . . . (to meet situational requirements). The more remote the elements in the new combination, the more creative the process or solution." Achieving a creative solution is facilitated by any conditions, ability, or tendency which brings the required associative elements into ideational contiguity. Mednick has three suggestions for bringing about this contiguity: (1) serendipity or accidental contiguity, (2) similarity of the associative elements or the similarity of the stimuli eliciting those elements, and (3) mediation of the required elements by other common elements. Individual differences in creativity are reflected in the size of the hierarchy of responses and in the distribution of associative strengths among members, the more creative person possessing a "flatter" distribution.

Maltzman's (1960) paper on the training of original thinking, like Mednick's, is concerned with facilitating creative or original thinking. Maltzman's approach, however, is considerably more "peripherally" oriented than Mednick's associationistic interpretation. Working within an operant-conditioning framework, Maltzman conceives the basic problem as devising means of increasing the operant level of uncommon-but-relevant responses. Once such behavior occurs, it may be reinforced, thus increasing the probability of further originality on the same and transfer tasks. Maltzman's method of stimulating uncommon responses (or raising the operant level of original responses) was to require S to free associate, always using different responses, to a repeatedly presented training list of stimulus words (Maltzman, Bogartz, & Breger, 1958). Originality induced in this manner was found to transfer to a second (test) list and to Guilford's (1950) Unusual Uses test.

Gagné's (1962) basic notion was that S cumulatively acquires a hierarchy of learning sets (or "subordinate knowledges") each level of which is a prerequisite for the acquisition of the next more complex and specific level. His method of identifying the subordinate knowledges or learning sets tends to be a little on the introspectionistic side which, in view of his applied interests in programmed learning, seems quite justifiable. The various knowledges are said to be identified, beginning

[3] For present purposes, the terms creativity and originality are considered to be approximately equivalent, although many authors make a distinction. For example, the most common distinction is that creative responses are those original (low frequency) responses which are useful.

with the final complex task and working to the simpler component tasks, by asking, "What kind of capability would an individual have to possess if he were to be able to perform this task successfully?" One repeats the question with the newly-defined tasks and so on. The knowledges become increasingly simple and general.

In his more recent problem-solving formulation (Gagné, 1964) the hierarchy of learning sets is replaced by a hierarchy of simple-to-complex forms of conditioning and learning. As in the 1962 paper, the performance of each level of task complexity requires the mastery of all lower levels. From bottom to top, the hierarchy now proceeds, slightly paraphrased: (1) response learning, (2) response chaining, (3) establishment of labeling responses, (4) concept learning, (5) principle learning, and (6) problem solving. In both papers Gagné sees the two major categories of variables as (1) S's relevant subordinate capabilities, and (2) instructions, which serve to identify terminal performance, identify parts of the stimulus situation, stimulate recall of the relevant subordinate capabilities, and channel thinking.

In relation specifically to anagram (scrambled letters) problems, Ronning (1965) reasoned that anagram problem solving can be conceived as a process of trial-and-error manipulation of the letters to form a word. This process is not entirely random, however, since S can "rule out" those permutations whose first two or three letters form bigrams and trigrams which do not appear in the English language, thus eliminating as many as 94 per cent of the possible permutations. He predicted and found that words having a "high ruleout total" could be solved faster than words having a "low ruleout total." Mayzner and Tresselt (1958, 1959; Mayzner, Tresselt, & Helbock, 1964) also emphasize implicit manipulation of anagram letters, which they sometimes refer to as hypotheses, but have evidence that the successive combinations may involve only a subset of the anagram letters. The observation of Mayzner, Tresselt, and Helbock (1964) that digrams in successive letter rearrangements tend to be in accord with digram frequencies in the language seems identical to Ronning's conclusion that low frequency digrams and trigrams are ruled out.

The above papers represent in the writer's opinion the most significant of the recent learning orientations to problem solving. It is obvious that while all authors begin with principles of conditioning and learning, and thus stress the acquisition of appropriate or inappropriate problem-solving responses, the final formulations emphasize quite different aspects of "learning" and different aspects of problem solving. For example, the papers differ considerably in the role of symbolic behavior, the emphasis of some conceptions being primarily at the peripheral level (Maltzman, 1960; Shultz, 1960), others relying heavily upon verbal associations (Kendler & Kendler, 1962; Mednick, 1962; Staats & Staats, 1963), and still others requiring numerous forms of implicit associative behavior (Campbell, 1960; Gagné, 1962, 1964; Mandler, 1962). As a final note, the award for stimulating the most research must go to Maltzman, whose originality training procedures (Maltzman, 1960) have been tested by Caron, Unger, and Parloff (1963), Freedman (1965), Gallup (1963), Penny and McCann (1962), and Rosenbaum, Arenson, and Panman (1964).

COGNITIVE-GESTALT APPROACHES TO PROBLEM SOLVING

The Gestalt interpretation of problem solving, of course, is the traditional antagonist of learning theory. While there are few recent papers which could be considered old-school Gestalt psychology, there still exists the traditional reluctance to reduce such terms as "cognitive organization," "fixation," "direction," and "insight" (and "factors of intellect" might be included) to more basic and comprehendable phenomena.

Hoffman (1961) presented a theory of creative problem solving which amounts to primarily a statement of the conditions which stimulate Ss to creative problem solutions. Briefly: At least two alternative cognitions (e.g., solutions, definitions of the problem, approaches to the problem) must exist and have approximately equal positive valence; thus neither can be accepted in preference to the other and an impasse is reached. The problem-solving unit (individual or group) is required to produce the best possible solution, thus omitting the possibility of either withdrawing from the problem (or "leaving the field") or accepting one or another alternative solution simply for expediency.

Sheerer (1963), in perhaps a more traditional Gestalt interpretation of problem solving, analyzed fixation behavior using several different insight-type puzzles and problems. He concluded that fixation can be caused by starting with an incorrect premise, failing to perceive a required novel use of a familiar object, and being unwilling to accept a detour. Also, fixation was said to be overcome and insight attained through a sudden "recentering" in the ways the problem or objects are perceived.

In Asher's (1963; Jacobsen & Asher, 1963) neo-field theory of problem solving he uniquely relates problem solving to learning in that "learning is a process of forming a concept within a cognitive system and problem solving is a process of disrupting established concepts . . . in this sense, problem solving is the inverse of learning." Problem solving, or attempts to disrupt concept constancy, is blocked by "contradisruptive defenses" whose purpose is to deny or reject the problem, thus maintaining concept constancy and homeostasis of the general cognitive system. Overall, problem organization serves to neutralize these defenses, allowing concept disruption. Concept disruption results in a state of tension or disequillibrium which produces "selective perception and fantasy," which in turn generate a series of alternate concepts (solutions), each of which has a different "coefficient of adequacy" for solving the problem.

A last cognitive-oriented paper, which has in common with the papers of Hoffman, Sheerer, and Asher only their mutual rejection of learning principles, is the factor analytic approach of Guilford. Merrifield, Guilford, Christensen, and Frick (1962) factor analyzed intercorrelations among 42 tests to determine the human abilities needed in problem solving. Fourteen factors, all said to involve semantic content, were extracted and the authors concluded that most problem-solving variance could be accounted for in terms of factors in the structure-of-intellect model (Guilford, 1950) and no new factors seemed to be required.

COMPUTER AND MATHEMATICAL MODELS OF PROBLEM SOLVING

Numerous papers and monographs related to the computer simulation of complex behavior have appeared and some of these are directly concerned with problem solving (Feigenbaum & Feldman, 1963; Neisser, 1963; Newell, Shaw, & Simon, 1958; Newell & Simon, 1963; Simon & Kotovsky, 1963; Uhr, 1963). The core of one computer simulation position is that human Ss process information (solve problems, memorize by rote, learn concepts) in a manner very similar to the programmed list-processing carried out by the computer (Simon & Kotovsky, 1963). Put slightly differently, Feigenbaum and Feldman (1963, p. 272) stated that the basic premise of the computer simulation approach is that complex thinking processes are built up of elementary symbol manipulation processes. According to Newell and Simon (1963), when an "intelligent program" is found that produces a sequence of rules for manipulating symbols which matches closely the behavior of the human S, then that program constitutes a good theory of the S's problem solving. The computer can be programmed to "learn" in the sense of storing information, including its own record of successes and failures, which can later influence the selection of a subroutine or of a possible solution. The simulation procedure does make the seemingly difficult demand that the researcher specify prior information, possible solutions, and the sequence of steps in problem solving (Hovland, 1960).

In discussing pattern-recognition computer models of form perception, Uhr (1963) presented an interpretation of Gestalt insightful learning which is quite similar to trial-and-error learning approaches to problem solving. Uhr suggested that the "concepts" which the machine forms in a trial-and-error fashion can later be used as tools to solve new problems "insightfully."

Restle and Davis (1962), presenting several related mathematical models of individual and group problem solving, produced a mathematically derived estimate of the number of stages involved in several insight problems which was in accord with intuitive judgments of the number of stages. The number of stages in a problem was taken to mean the number of ideas required to obtain the solution, and more complex problems were presumed to require more "stages."

As with the cognitive and Gestalt interpretations of human problem solving, the computer and mathematical models function at a more molar level of behavior than do many associative learning notions. Unlike the cognitive-Gestalt orientations, these models do not necessarily reject learning concepts, especially the mathematical-models approach which, of course, has its roots in stimulus sampling theory, a form of S-R psychology.

III

PROBLEM SOLVING AS TRIAL-AND-ERROR LEARNING

In spite of the striking variability among laboratory tasks called "problem solving," there is one property which each problem-solving task has in common with all other problem-solving tasks, laboratory and "real world" alike, which clearly relates problem solving to other forms of learning: In every problem-solving situation correct responses are selectively reinforced and incorrect responses are not reinforced. Perhaps the most significant difference between problem solving and other forms of learning is that, in most problem-solving tasks, the response alternatives are not clearly defined for S. Therefore, from the problem stimuli presented and instructions concerning the goal, S generates his own hierarchy of response alternatives which he sequentially tests and rejects until the correct response, or correct combination of responses, is rewarded via solving the problem. This sequential testing and rejecting of response alternatives has been called trial-and-error learning (Davis, 1965, in press; Staats & Staats, 1963, p. 103) and may be said to rearrange S's initial hierarchy of responses primarily by strengthening the (initially weak) correct response alternative.

Quite clearly, the "problem-solving process" is known to have properties, particularly suddenness of solution or "insight" as it is often called, which result from "thinking" or "reasoning"—not from overt trial-and-error behavior. The solution to this puzzle leads to two basic forms of problem-solving tasks with two concomitant forms of problem-solving behavior. Both categories of problem solving are, in fact, based upon trial-and-error learning. The critical distinction between the forms of problem solving depends simply upon whether Ss can or cannot associate a particular outcome or function to each of the available response alternatives. This will determine whether the trial-and-error behavior is covert or overt, respectively.

PROBLEM SOLVING TYPE O

When the outcome of the various response alternatives is unknown, S must begin the problem-solving session with overt trial-and-error behavior in which he manifestly tests various response alternatives to determine their potential outcomes; i.e., he acquires the necessary stimulus-response-outcome associations. He may now covertly and serially consider each response alternative, including combinations of responses, one of which would meet solution requirements. Tasks differ greatly, however, in the relative amounts of overt vs. covert behavior. Some Type O problems, those most resembling animal discrimination learning situations, require overt trial-and-error response testing throughout the task, e.g., Kendler and Kendler's (1962) reversal-nonreversal problems and other concept-learning problems and probability-learning tasks (Stevenson & Weir, 1963; Weir, 1964). Other Type O problem-solving tasks have a more readily identifiable implicit trial-and-error (or "reasoning") aspect which follows the acquisition of the necessary associations, e.g., problems modeled after Maier's (Maier & Schneirla, 1935) rat-reasoning experiments (e.g., Kendler & Kendler, 1961).

PROBLEM SOLVING TYPE C

When the outcomes or functions of the response alternatives are known to S, due perhaps to pre-experimental trial-and-error learning, the problem can be solved by covertly testing and rejecting response alternatives without recourse to overt responses prior to demonstrating the problem solution.

DISTINCTIONS BETWEEN TYPES O AND C PROBLEM SOLVING

These two basic categories of problem solving differ along a number of roughly dichotomous dimensions. First, in the Type C (covert) tasks, as noted above, the outcomes of the various response alternatives are known, thus the role of pre-experimental associations is central. Secondly, the behavior sequence is unobservable. Thirdly, concrete tasks are used, e.g., the pendulum problem involving fairly familiar stimulus materials (thus providing the pre-learned associations). Fourthly, mentalistic concepts are sometimes used, such as set or functional fixity, often clearly in the Gestalt tradition. Finally, the scoring is usually all-or-none, except when time measures are used.

Contrasted with the above, in the Type O tasks, those requiring overt trial and error, outcomes of the various alternatives are not known, thus minimizing the role of pre-experimental associations. Secondly, the behavior is of necessity an externalized trial-and-error learning process. Thirdly, unfamiliar (abstract) stimulus materials are typically used, such as in switch-light problems, concept learning problems, and probability learning tasks. Fourthly, behavioristic learning concepts predominate, and the concern is often with basic variables shown to influence other forms of learning. Finally, scoring is usually continuous, since the behavior sequence is externalized, and is often multidimensional.

There are, of course, cases which do not reflect all of these "usual" distinctions between Type O and Type C problem solving. For example, learning concepts are often applied to Gestalt-founded tasks (e.g., Glucksberg, 1962). Also, it could be argued that arithmetic and water-jar problems (Type C tasks) deal with abstract rather than concrete stimulus materials.

In general, the present interpretation of problem solving as overt (Type O) or covert (Type C) trial-and-error behavior is not completely original or unique. Numerous sources have already been cited which recognize the roles of overt and/or covert trial-and-error behavior in thinking and problem solving, and basically similar ideas are apparent in Thorndyke's trial-and-error learning and Tolman's symbolic trial-and-error. The primary value of this approach is that the empirical results in the many areas of problem solving seem quite amenable to "explanation" under the suggested two-process interpretation. The following problem-solving research is thus categorized according to whether the tasks elicit primarily Type C vs. Type O problem-solving behavior.

IV

TYPE C PROBLEM SOLVING TASKS

Laboratory problems which can be solved without overt trial-and-error responding (Type C tasks) appear to fall into three identifiable categories: (1) anagram problems, (2) water-jar and arithmetic problems, and (3) "insight" problems.

Anagram Problem Solving

Several E's have designed their anagram problem-solving experiments and interpreted their various results in terms of the facilitating vs. detrimental effects of long-term language habits. There has been an especial fixation with the effects of letter transition probabilities (or bigram frequencies) of both the anagram and the solution word upon solution times. Tables are available (e. g., Underwood & Shulz, 1960) which give the frequency of occurrence of 2-letter units (bigrams) in the language. The "bigram frequency total" is simply the sum of the tabled frequencies of all adjacent bigrams in any given anagram or solution word.

Mayzner and Tresselt (1959) found that anagrams composed of bigrams which occur with relatively high frequency in the language were more difficult to "break up" or rearrange into the solution word than anagrams composed of low-frequency bigrams. On the other hand, if the solution word included bigrams which occur with high frequency, anagram solving was easier than if the solution word included low-frequency bigrams (Mayzner & Tresselt, 1962a). The relationship between problem-solving ease and solution-word bigram frequency is further strengthened when word length and letter position variables are taken into consideration (Mayzner & Tresselt, 1962b, 1963). Also, when movable letters (mounted on blocks) and "think out loud" procedures were used, both of which allowed recording of successive letter rearrangements, Mayzner, Tresselt, and Helbock (1964) found that the relative frequencies of the rearranged digrams were in accord with digram frequencies in the language.

Interested in Mayzner and Tresselt's (1959) finding that anagrams composed of high-frequency bigrams were difficult to rearrange, O'Connell and Duncan (1961) found that wide spacing between anagram letters (10 typewriter spaces) would improve solution times, perhaps by weakening the learned associations between letters. In an apparent attempt to further clarify any independent and interactive effects of anagram bigram frequencies, solution-word bigram frequencies, and letter spacing, Dominowski and Duncan (1964), first of all, failed to replicate Mayzner and Tresselt's (1959) finding that anagrams with high bigram frequencies were more difficult than anagrams with low bigram frequencies. Secondly, they failed to replicate Mayzner and Tresselt's (1962a) finding that anagrams whose solution words had high bigram frequencies were more easily solved than when the solution words had low bigram frequencies. Lastly, they failed to replicate O'Connell and Duncan's (1961) finding that wide spacing of anagram letters facilitated solution times. The one consistent finding in the three experiments of Dominowski and Duncan was the interaction of anagram bigram frequency with solution-word bigram frequency: The best performances occurred when anagram and solution-word bigram frequencies both were low or else both were high. They suggested that low-frequency bigrams elicited, as implicit responses, other low-frequency bigrams while high-frequency bigrams elicited other high-frequency bigrams.

Stachnik (1963) also reported a failure to replicate the Mayzner and Tresselt (1959) finding. He attributed this failure to the use of paper and pencil which allowed his Ss to proceed from each subsequent revision of the letters rather than return to the original anagram after unsuccessful letter manipulations. Since subsequent revisions tended to have lower transition probabilities, any detrimental effect of high transition probabilities in the original anagram was obscured

Beilin and Horn (1962) found that solution times were longer when meaningful words, instead of scrambled letters, were used as the anagram. (The words could be rearranged into other unrelated words.) Within a Gestalt framework, they concluded that, independent of transition probabilities, the meaningful units "resisted reorganization" more than did the nonsense units. Ekstrand and Dominowski (1965) similarly found that real words used as anagrams were indeed more difficult than when scrambled letters were used. Their somewhat different interpretation was that implicit associates to the word problems interferred with S's problem solving since the solution word was rarely among the associates. They also found letter spacing to be an ineffective variable in either word or scrambled-letter anagram problems.

Two anagram experiments were concerned with mental set. K. G. Davis and Hess (1962) found a very close relationship between the degree of awareness of the pattern set (a set to use a specific rearrangement of letters, e.g., 23451) and utilization of that set, thus failing to support the conclusion of Rees and Israel (1935) that the pattern set could operate without awareness. In relation to the category set in anagram problems, a set to respond with words from the same conceptual category, Safren (1962) found that anagrams in organized lists, containing words which elicit each other in free association, were solved more easily than anagrams from random lists. She concluded that Deese's (1959) interitem associative strength functions similarly in verbal recall and in solving anagrams.

Tresselt and Mayzner (1960) used a novel variation of anagram problem solving in requiring Ss to solve just one of two or more alternative anagrams. The rate of switching to other anagrams increased with more available problems and with instructions that only one of the available anagrams was solvable. Continuing with this methodology, Jenkins and Mayzner (1961) found that over time Ss progressively switched less often, especially with only two available anagrams as compared with three, and that prior experience with easy vs. difficult anagrams did not influence later switching rate. They proposed that switching occurs when the rate of formation of new hypotheses (implicit tentative rearrangements of the letters) for a given anagram falls below the expected rate for another alternative by some critical amount.

Related to the decreasing rate of hypothesis generation mentioned Jenkins and Mayzner, both Mayzner and Tresselt (1958) with anagram problems and Duncan (1962) with Maier's Two-string problem found that most problem solutions occurred early in the allotted time period. Both papers reported a near-perfect linear relationship when cumulative solution frequency was plotted over log solution time.

On the topic of stress, Fine, Cohen, and Crist (1960), investigating the effects of climatic conditions upon "complex mental performance" in the form of anagram problems, found the marginally best performance after six and a half hours in the most hot and humid experimental condition. Also, Nance and Sinnot (1964) found that adding time pressure improved anagram solving considerably. Nance and Sinnot also concluded that practice in solving anagrams did not reduce solution times but did reduce variability and that requiring overt verbalization slowed performance on hard anagrams but speeded performance on easy problems (Nance & Sinnot, 1963).

As a final note, anagram problem solving represents the most clear support for the notion that some problem solving is largely a matter of implicit trial-and-error behavior (Mayzner, Tresselt, & Helbock, 1964; Ronning, 1965; Stachnik, 1963). Indeed, the very nature of the task, rearranging the letters to form a word, requires S to covertly and serially generate recombinations of the available letters. These implicit letter rearrangements can be externalized by allowing paper and pencil (Stachnik, 1963), by using movable letters (Mayzner, Tresselt, & Helbock, 1964), or by requiring S to "think out loud" (Mayzner, Tresselt, & Helbock, 1964). Also it is important to note that the trial-and-error rearrangements are not random but are influenced by such variables as the letter transition probabilities found in the language (e.g., Mayzner, Tresselt, & Helbock, 1964; Ronning, 1965; Stachnik, 1963).

Water-jar and Arithmetic Problems

All experiments reviewed using water-jar problems were concerned with mental set. This may reflect a recognition of the importance of high-dominance incorrect response tendencies (i.e., set solutions) in human problem solving (Davis, 1965, in press). On the other hand, what else can one do with water-jar problems?

Bugelski and Huff (1962) noted that if S were to make errors in Luchins' (1942) computationally difficult problems, he would reject the set solution. They presented a new set of water-jar problems which were simpler, required a systematic and routine approach, and which would produce a fully strengthened set after three problems. Also critical of Luchins' procedures, Aftanas and Koppenaal (1962) concluded that Luchins' instructions produced some set by failing to inform S that more than one solution might be available. They showed that fewer set solutions occurred when Ss were shown alternative solutions to the same practice problem.

Jacobus and Johnson (1964) demonstrated an "experimental set to adopt a set." They found that Ss who first solved 10 anagram problems with a set solution solved more of their nine water-jar problems by a set solution, plus failed more extinction problems, than did Ss without the set experience.

Following-up earlier evidence of simple associative learning and extinction in problem-solving set (Gardner & Runquist, 1958), Runquist and Sexton (1961) found that an extinguished water-jar set solution would spontaneously recover with time.

In arithmetic problem solving the emphasis has been notably different than with anagram or water-jar problems. With arithmetic problems, there is virtually no interest in the task itself except as representative of some larger category of "complex mental behavior." Thus, in the literature reviewed, there were no systematic investigations of task, pretraining, or instructional variables which might determine some sources of difficulty in solving various types of arithmetic problems.

Numerous experiments were concerned with the effects of stress upon arithmetic problem solving. Kurz (1964), using mental multiplication tasks, found that pacing (time stress) decreased solution times without increasing errors, while performance was unaffected by shock or auditory distraction. Also concerned with auditory distraction or noise stress, Woodhead (1964) cited numerous studies which, in conjunction with her own experiments, led her to conclude that only intensities above 90 db would impair arithmetic problem solving.

Orr (1964) reported a sleep-deprivation experiment in which two male Ss performed coordination and vigilance tasks for 21 consecutive hours. Scores on math problems which were solved concurrently with the vigilance tasks declined noticeably less over the session than either the psychomotor or vigilance performance. Investigating the effects of hypoxia on problem solving, Phillips, Griswold, and Pace (1963) found that the extra effort exerted under high-altitude (14,250 ft.) conditions improved performance on numbers problems but impaired solving word-rhymes problems due to increased competition from strong alternative responses.

Results of these experiments, together with the facilitating effects of time pressure upon anagram problem solving found by Nance and Sinnot (1964), improved anagram performance under hot and humid working conditions found by Fine, Cohen, and Crist (1960), and the lack of effect of noise stress on anagram problem solving with schizophrenic Ss (Cowden, 1962), seem to suggest that thinking by the adaptable human organism is not particularly disturbed by at least minor stresses and distractions.

Klausmeier and Loughlin (1961) used arithmetic problems in which 11-year-olds were given actual coins and bills and were required to, e.g., make $9.77 using 12 bills and coins. In analyzing problem-solving behaviors as a function of IQ, they found that high IQ Ss were markedly superior in verifying proposed solutions (and therefore submitted fewer incorrect solutions), were more efficient, more persistent, and tended to use more logical approaches than average or low IQ Ss.

Also working with children, Hudgins (1960) found that fifth grade Ss working in four-man groups solved more "story" problems than Ss working individually. However, later individual problem solving did not improve as a result of the group problem-solving experience.

Some experiments have used number-series tasks of the variety found in some intelligence tests. Typically, a string of numbers is presented and S is asked either to induce the next number in the series or to produce a formula for the series. These tasks are not strictly "arithmetic" problems in the usual sense. Indeed, alphabetical letter-series problems seem quite similar in nature (e.g., Simon & Kotovsky, 1963).

Gagné and Brown (1961) devised three learning programs for teaching Ss to find formulae for number-series problems. The programs differed in size of step and in the degree of encouraging discovery of general principles. Their transfer tasks, which required finding formulae for new number series, were better performed by Ss whose training involved systematic, small-step reinstatement (active reproduction) or learned concepts.

Wescott (1961; Westcott & Ranzoni, 1963) used number-series and letter-series problems in which the S himself determined how many units of the series he saw before offering a solution. Thus two apparently unrelated dependent measures were available, the number of units S would require before making an "intuitive leap" (information demand) and the success of that solution. His analysis of individual differences in making intuitive leaps, or intuitive thinking ability, resulted in four types of problem-solvers based upon all combinations of high-low information demand and high-low success; e.g., successful intuitive thinkers were low in information demand but high on success.

"Insight" Problems

Most recent experiments with "insight" problems have dealt with either pretraining and transfer effects or with motivational variables. To anticipate the experimental findings related to transfer, it is not surprising to find that transfer effects can be either positive or negative due to the strengthening of correct or incorrect response alternatives, respectively. When no transfer effects are found, it can be assumed that the pretraining was irrelevant; i.e., the hierarchy of responses altered by pretraining was not the same hierarchy to be elicited by problem stimuli. It is surprising, however, and perhaps enlightening, that some of the transfer effects found would not be predicted easily.

Duncan (1961) concluded that performance in Maier's Two-string problem could not be influenced by training procedures which provide non-specific transfer. In three experiments, Ss "actively" listed uses for the pair of pliers to be used as a weight in the problem; in two more experiments Ss "passively" were instructed to look for unusual uses for stimulus objects; and in a sixth experiment Ss recieved practice on another insight problem. There was no indication of any facilitation by any of the pretraining procedures, and Duncan interpreted his results as supporting Campbell's (1960) position that the search process involved in solving insight problems is largely blind trial-and-error.

Hyman (1961) used an Automatic Warehouse problem which required Ss (engineers) to devise a system which would automatically recognize boxes complying to certain specifications. He found that Ss who constructively listed the advantages of sample solutions later produced a larger number of alternative solutions and a more creative final solution than Ss who criticized the sample solutions. Ss in the constructive evaluation condition also gave more and better solutions in an unrelated task (suggesting applications for a particular chemical phenomenon). Hyman cited papers by Torrance (1959) and Torrance and Harmon (1960) in which essentially the same results were found, including positive transfer to an unrelated task.

Saugstad's Ball problem (Saugstad & Raaheim, 1960) included transferring steel balls from a glass into a metal cylinder and, like many insight problems, required novel uses for familiar objects; e.g., a newspaper had to be rolled into a tube through which the balls were rolled into the cylinder. Not surprisingly, Ss who were shown these two critical functions solved faster than Ss without such information. The results were interpreted as congruent with Saugstad's emphasis upon the availability of functions as crucial to problem solving. Using a similar task, substituting peas for steel balls, Raaheim (1963) later concluded that specific response objects (e.g., the newspaper) were of less significance than the general class of objects (tubes or ladles) appropriate for that type of situation.

Hoffman, Burke, and Maier (1963) found that prior experience with a simpler version of Maier's Hat-rack problem, in which Ss were encouraged to try a variety of solutions, led to greater variability and thus more wrong solutions in the later problem than no experience at all. They also found that positive vs. negative verbal reinforcement had no effect on performance and concluded that reinforcement is irrelevant for problem solving.[4] Sechrest (1963), however, working with children, found that either positive verbal reinforcement or the absence of negative verbal reinforcement did improve performance on a jig-saw puzzle.

Glucksberg (1962) used the Candle problem (Duncker, 1945) to successfully test the prediction that high drive would facilitate problem solving when the correct response was dominant and retard performance when the correct response was lower in the habit-family hierarchy. In a second perceptual task (word recognition), the same interaction of drive with response dominance was found. These effects of drive were later replicated with an original electrical wiring problem (Glucksberg, 1964b). In all tasks, high drive was induced by offering large monetary rewards.

Again using the Candle problem, Glucksberg (1964a) blindfolded the Ss in order to allow E

[4] It could be cogently argued, however, that the feedback function of reinforcement, though not always the motivational function, is absolutely indispensable. Without reinforcing feedback, S would not know if his "direction" were correct.

to determine if solution occurred exactly when S "observed" (touched) the crucial thumbtack box. In testing this contiguity hypothesis, Ss were given the difficult or low dominance version of the problem; i.e., the box upon which the candle must be mounted was filled with thumbtacks. As predicted, all eight Ss used the box immediately after touching it, although not necessarily after the first time the box was touched.

Johnson has used a serial-exposure box to measure time spent in either of two phases of problem solving, a preparation phase and a solution phase. The box contained two compartments which S could illuminate separately, never simultaneously. In the preparation phase S viewed problem stimuli presented in one compartment and was said to be engaged in a formulation or induction process. For the solution phase, he switched over to the choices presented in the other compartment and picked (or deduced) a solution from among the alternatives presented. If S switched back for a second look at the first set of stimuli, this was called reformulation. Johnson's serial-exposure method has been used with figure-concept learning problems (Johnson, 1961), verbal concept learning problems (Johnson & Hall, 1961; Johnson & Jennings, 1963; Johnson, Lincoln & Hall, 1961), and analogy problems (Johnson, 1962). While Johnson's tasks and procedures are somewhat different than the above "insight" problems, it seems likely that, particularly if both the problem stimuli and the response alternatives are viewed simultaneously, S might be conceived as solving by implicit trial-and-error much as with other problems in this section.

V

TYPE O PROBLEM-SOLVING TASKS

Type O problem-solving tasks are those learning situations in which S must first acquire the necessary associations or experiences, in a trial-and-error fashion, which he then draws upon or combines to solve the problem. Several laboratory tasks which fit this description are relatively well standardized and hence boast research too extensive to be completely reviewed here. Specifically, concept learning and probability learning (and the related decision-making and game-theory research) are examples of Type O problem solving. It is important to note that these "standardized" Type O tasks are in fact referred to as problem solving or intimately related to problem solving by numerous writers (e.g., Duncan, 1959, 1965; Griffin & Beier, 1961; Kendler & Kendler, 1962; Stevenson & Weir, 1963; Weir, 1964). To perhaps impose organization, this section is composed of four subcategories, (1) switch-light problems, (2) classification tasks, (3) probability learning, and (4) miscellaneous.

Switch-light Problems

All switch-light tasks require S to achieve a particular pattern of lights in a row or matrix of lights by operating switches on his response panel. Since S initially does not know which lights are controlled by each switch, he must approach the task primarily through overt trial-and-error behavior. As he acquires the necessary switch-light relationships, or if he has learned the necessary S-R relationships in pretraining, the problem-solving behavior becomes implicit (Davis, 1965, in press). Other than a clear methodological similarity, however, the following switch-light tasks have little in common.

Duncan (1963), using a task in which S attempted to attain a particular light pattern in a row of seven lights by operating the seven switches on his response panel, found that Ss who were instructed to think made fewer overt responses (switch presses) but took longer to solve than Ss not so instructed. In a second experiment, Ss who were given "complete" information about the operation of the apparatus (arrows indicated the combination of lights operated by each switch plus Ss were given a careful explanation of the independent on-off operation of the individual lights) performed better than Ss given "some" information (arrows only).

Pylyshyn's (1963) switch-light task involved four pairs of lights and seven switches. At all times, either the top or bottom of a given pair was on, but not both. The task was to manipulate the two-position switches until only the top light of each pair was on. Compared to a statistical model called the random scan algorithm (which simply assumes that trials are made at random but unsuccessful trials are not repeated), human Ss made significantly fewer moves which suggested that "some inductive inferences were being made" in the form of gaining information from partial solutions (turning some top lights on).

Davis (1965, in press) parametrically manipulated several variables in a switch-light task which were interpreted as dimensions of the behavioristic habit-family hierarchy. Performance worsened (1) with increases in the number of distracting (reinforced but incorrect) switches present in a problem, corresponding to the number of high dominance incorrect responses in S's response hierarchy, (2) with increases in the number of switches which S was required to use in order to solve the problem, interpreted as the number of responses which must be combined or chained for problem solution, and (3) with increases in the total number of available switches, corresponding to increases in the size of S's habit hierarchy. In another experiment, Davis demonstrated the continuity between overt (Type O) and covert (Type C) problem solving by teaching some Ss (Group C) exactly which lights were controlled by each switch prior to solving their problems. These Ss exhibited errorless, long-latency, "reasoning" or "insightful" problem-solving behavior in contrast with the overt trial-and-error approach of untrained Ss (Group O).

Investigating relationships between EEG activity and thinking, Beckman and Stein (1961) found a rank-order correlation of -.47 between per cent alpha rhythms recorded during a rest interval and performance on John's (1957) PSI apparatus. They interpreted this result in terms of the relationship between attention (arousal) and decreased alpha rhythms, more efficient problem solvers being more attentive to external and internal stimuli.

Classification Tasks

In Morrisett and Hovland's (1959) frequently cited study, two easily discriminable stimulus patterns (e.g., triangle & square) were presented in four horizontal-vertical spatial arrangements corresponding to four response categories. Different problems simply involved the use of different pairs of stimulus patterns. Transfer to a test problem, interpreted as learning-to-learn, was best for Ss who learned several problems each to a high degree (64 trials on each of 3 problems) rather than learning many problems to a low degree (8 trials on each of 24 problems) or receiving all trials on just one problem.

Mandler and Cowan's (1962) task for studying "the learning of simple structures" involved basically a two-response paired-associates procedure. A given 6-item list was made up of three different CVC trigrams, each item consisting of an ordered pair of these trigrams. The S's task was to learn which pairs were associated with Attribute R (a checkmark) and which pairs were not. As predicted, lists with unequal category sizes were learned more easily than lists with three items in each category. Also, performance was related to the logical structure of the elements; for example, symmetry (both AB and BA have checkmarks) facilitated learning.

There are just six structurally different ways to divide the eight stimulus patterns produced by combinations of levels within each of three two-level dimensions into two subgroups of four stimuli each. Three recent studies have been concerned with the ease of learning these two-group classifications. Shepard, Hovland, and Jenkins (1961) found, among many other things, that the relative difficulty of learning corresponded in large part to the number of dimensions relevant to the partition. When the eight stimulus patterns differed along two continua, brightness and saturation of the color red, Shepard and Chang (1963) found the difficulty of six classifications to be highly related to the number of pairwise confusions among the stimuli; i.e., a principle of stimulus generalization explained most variance.

In the third study, Davis and Bourne (1965) investigated the effects of two response types upon learning the six classifications. One group of Ss was required to associate one verbal response to one subgroup of four stimuli and another verbal response to the other four stimuli. This condition basically replicated the procedures and results of Shepard et al. (1961). In addition, the results showed that the most complex two-group classification (Type VI of Shepard et al.) was more difficult than a rote-learning control task in which eight unrelated responses were assigned to the eight stimuli. For the other groups of Ss, the four stimuli in each subgroup were to be associated (one each) with four conceptually related words (e.g., four animal names vs. four flower names). While the six classification types did not differ among themselves when the conceptually related responses were used, all were more difficult than the rote task. Of methodological interest was the observation that among the Ss using just two responses, several Ss reported attending to only the four stimuli associated with one response. These Ss learned more efficiently than did Ss who attended to all eight stimuli and both verbal responses.

Bourne (1965) analyzed hypotheses and hypothesis changes as a function of correct responses and errors in learning to classify consonant clusters. The correct classification depended upon whether one or two relevant consonants appeared in capital vs. small letters. He found that the most efficient learners tended to generate hypotheses which were consistent with previous information, tended to change hypotheses after an error instead of after a correct response, and tended to make simple and systematic hypothesis changes (one-dimension only).

Probability Learning

In a probability-learning situation "solving the problem" is defined as the adoption of the maximizing strategy, i.e., always choosing that alternative which is most frequently reinforced. Investigating the effects of age and verbalization upon performance, Stevenson and Weir (1963) used a three-choice task in which one response knob paid off 33% of the times it was pressed, while responses to the other two knobs were never reinforced. This task has the novel attraction of being unsolvable in the sense that S can never reach a 100% pay-off level, thus allowing E to determine the length of the problem-solving session. Stevenson and Weir found that the incidence of correct responses increased with age, using 12-, 15-, and 18-year-old Ss, and it made no difference if Ss were tested alone or in pairs. Verbalized explanations of response choices indicated that most responses were dependent upon structure (e.g., Ss looked for patterns or recurrent sequences) or upon previous responses (e.g., positive and negative recency effects). Also, Ss who were not required to explicitly verbalize reasons for response choices did not perform differently than Ss who did verbalize.

Weir (1964) found that 3- and 5- year-old Ss and college students tended to maximize more than the "middle-age" group of 7-, 11-, and 15-year-olds. He reasoned that the youngest Ss were simply responding to the reinforced stimulus, the middle group had inadequate use of strategies, and older Ss were able to use complex strategies which, while slower in reaching asymptote than the youngest group, also eventually led to maximizing.

In a novel hide-and-seek probability learning task (Stevenson & Odom, 1964), the E hid toys so that S would be reinforced on 75% of his choices of one box, 25% of his choices of another box, and 0% of his choices of a third box. On alternate trials, the S hid the toys and E did the seeking. The E either chose boxes randomly or according to a fixed 75:25:0 schedule. The S could obviously "solve" the first aspect of the task (seeking) by maximizing, i.e., always choosing E's 75% box. In the second (hiding) part of the task, he could solve the problem or maximize payoff, at least in the fixed condition, by always hiding toys in the box which E never chose. The results indicated that on later trials, the 7- to 8-year-old Ss performed better on both parts of the tasks than did 3- to 5-year-olds or 10- to 12-year-olds.

Peterson and Ulehla (1964) used an "inference task" in which S observed a cue and, on the basis of the information provided by the cue, predicted which set of criteria would occur. They found, among other things, that as the predictive validity of the cue decreased, S took longer to make a decision, was less confident in his prediction, rated the task as more difficult, and, of course, he was less likely to be correct in his prediction (or inference).

In another form of weighted cue problem in which S had to discover, first, which cues were relevant and, secondly, how each was weighted, Mattson (1965) investigated the relative efficacy of the three kinds of transfer suggested by Mandler (1962). Transfer attributed to warm-up (pretraining with an unrelated task) produced the greatest facilitation, learning-to-learn (practice with similar tasks) was next, and cue repetition produced the least positive transfer.

Miscellaneous Tasks

Reviewed in this section are problem-solving tasks which have in common only a heavy reliance on overt trial-and-error behavior. With few exceptions, the experiments defy further organization in terms of the specific task used, variables manipulated, results or theoretical implications.

Kendler and Kendler (1961) taught children to acquire one subgoal (marble) by operating one manipulanda and to acquire another subgoal by operating the second manipulanda. In a separate task, they learned that one of the subgoals could be used to produce the major goal (M & M candy). In the test, Ss inferentially acquired the correct subgoal, using it to attain the major goal, and it made no difference which habit-segment was learned first.

Sassenrath (1963a, 1963b), in comparing the effects of drive as measured by the Test Anxiety Questionnaire (TAQ) vs. the Manifest Anxiety Scale (MAS), used a "concept-learning" task in which Ss were required to respond to each stimulus word with a number from one to nine. The number was "correct" if it was equal to the number of letters in the word minus one, e.g., hospital—7, good—3, etc. In a transfer task, the number response was correct if it was equal to 11 minus the number of letters in the stimulus word, e.g., hospital—3, good—7, etc. The results indicated that low drive Ss, as measured by TAQ, performed better in both the training and transfer tasks compared to high TAQ drive Ss, while MAS drive level was inconsistently related to performance in the two tasks. Interested in the effects of set instead of drive, Janke (1962) used Sassenrath's task and found that Ss who were instructed to look for a principle solved the problem in fewer trials than Ss who were told to look for a verbal concept (i.e., a solution related to word meaning), who in turn performed better than Ss who were told that only extrasensory perception could help.

Two experiments dealt with learning alternation problems. The task of Linker and Ross (1963) required S to locate and predict regularity (single, double, or quadruple alternations) in either one or two of three possible stimulus dimensions. They concluded, mainly, that alternation length (single, double, quadruple) was not related to solution difficulty and that Ss tended to use hypotheses rather than "reading off from memory or learning on an incremental basis." Shoonard and Restle (1961) found that a double alternation problem in which a fixed stimulus pattern (AABB) was reinforced was more easily learned than when reinforcement was contingent upon S's responses such that any double alternation pattern would be correct and any deviation wrong.

Ericksen (1962) used a triangle-shaped, spatial-temporal walking maze which was learned by two groups of Ss. Perception (or place) learners were not blindfolded and were said to learn the maze primarily by spatial and environmental cues. Abstraction (or response) learners were blindfolded and thus forced to "abstract temporal and directional relations out of the maze environment." While there were no differences between the two groups in learning the original maze, the blindfolded group performed consistently better on two transfer tasks (a rotation of the walking maze and a 9-in. push-button maze), both of which required the same sequence of moves as the original maze.

Donahoe (1960) compared two types of feedback in a task which required S to guess a predetermined point on a 7 × 7 grid. The Ss given one feedback source of "nearer," "farther," or "same" after each guess solved faster than Ss who were given longitude and latitude information separately, although the latter separate feedback condition logically would have allowed faster elimination of incorrect grid points.

Neimark and Wagner (1964) used a task in which Ss were presented a covered pattern of eight binary elements (black or white circles). The Ss' task in each of six problems was to uncover one element at a time, in any S-determined order, and attempt to determine the final pattern in as few "moves" as possible. Different groups were provided with answer sheets containing 8, 16, or 32 possible solutions (final element patterns) which could be progressively eliminated on the basis of the sequentially acquired information. They found that the number of information-getting moves and time to solution were an increasing linear function of the number of possible solutions.

Saltz and Newman (1960) investigated the effects of prior learning of names of parts upon assembly of a hydraulic regulator. The effect was non-linear: Paired-associates pretraining in which the name of the part was paired with a picture of the part learned to a low criterion (12 of 15 correct) produced significantly fewer errors than either no verbal pretraining or learning to a high criterion (three successive correct trials).

Using a less complex mechanical task, Blumenfeld (1964) gave himself 50 trials with a bent nail puzzle. Since solution times showed no improvement, he concluded that chance, rather than repetition or reinforcement, was the primary determinant of success in this task.

VI

DISCUSSION AND CONCLUSIONS

The current interpretation of problem solving as either <u>covert</u> or <u>overt</u> trial-and-error behavior does seem to demonstrate some continuity among the great variety of tasks and procedures called "problem solving." When, due to past experiences, <u>S</u> can associate outcomes or functions to the available response alternatives (or stimulus materials) he may solve some problems (Type C tasks—anagram problems, "insight" problems, and water-jar and arithmetic problems) by covert behavior. This implicit responding will consist of the sequential testing and rejecting of response alternatives until one response, or combination of responses, is rewarded by solving the problem. Observers of this type of problem-solving behavior often conclude simply, and after the fact, that <u>thinking</u>, <u>reasoning</u>, or <u>insight</u> has occurred or that <u>S</u> possesses the necessary <u>direction</u> or <u>functions</u>.

On the other hand, when <u>S</u> cannot initially associate outcomes or functions to the available response alternatives (or stimulus materials), as in switch-light problems, classification problems, probability-learning tasks, or in any of the miscellaneous Type O tasks described above, he must first acquire the necessary S-R relationships by overt trial-and-error before the problem can be solved. Some tasks in this category resemble animal operant-discrimination learning because of the visible role of reinforcement or reinforcing feedback.

One shortcoming of organizing problem-solving research according to the nature of the task is that variables or topics which might be common to different categories of tasks could be ignored. Actually, however, not many variables were common to more than a few individual experiments.

One topic, the notion of "transfer" (which includes <u>practice</u>, <u>pretraining</u>, <u>set</u>, <u>fixation</u>, and <u>available functions</u>) did reappear in various reports with substantial regularity. It might be noted that, unless some form of practice or pretraining is given specifically by <u>E</u>, transfer is a critical determiner of performance primarily in Type C problem-solving. These tasks typically use familiar stimulus materials, thus providing the pre-established associations which can transfer, positively or negatively, to the problem situations. Transfer is less often of interest in the Type O tasks which depend heavily upon associations formed by overt trial-and-error in the experiment itself. In both Type C and O tasks, of course, <u>E</u> can give pretraining which can result in positive (Hyman, 1961; Mattson, 1965), negative (Hoffman, Burke, & Maier, 1963; Luchins, 1942), or zero transfer (Blumenfeld, 1964; Duncan, 1961; Hudgins, 1960).

One less recurrent topic was that of motivation, which is here taken to include the effects of incentives, stress, and some personality variables (i.e., those measured by TAQ and MAS). The results of experiments dealing with these various aspects of drive are somewhat curious: As predicted by traditional S-R theory (e.g., Spence, 1958), drive manipulated by incentives sometimes helps and sometimes hinders, depending upon the high or low position, respectively, of the solution in <u>S</u>'s hierarchy of responses (Glucksberg, 1962; 1964a). This relationship apparently does not hold with anxiety-type drive as measured by TAQ or MAS (Sassenrath, 1962, 1963a, 1963b). Drive in the form of stress usually improves problem solving (e.g., Fine, Cohen, & Crist, 1960; Kurz, 1964).

As a final note, one serious omission in the present paper should be mentioned. The research on originality training stimulated by Maltzman (1960) has only been cited, not even briefly discussed. Also, there exists a series of papers by Parnes and Meadow and others dealing with the training of creative problem solving which have not been summarized here (e.g., Johnson & Zerbolio, 1964; Parnes, 1961; Parnes & Meadow, 1959, 1960). These and other important papers dealing with the training of original and creative problem-solving behaviors are the topic of a future review.

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